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Research Paper

Spatial market integration and short-run dynamics under varying data periods: Evidence from maize markets in Karnataka, India

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ABSTRACT : The paper examined the dynamics of spatial integration and speed of price adjustment to long-run equilibrium in maize markets in Karnataka across different data periods. Monthly time series data from major maize markets in Karnataka were split into three time periods, 2002-2008, 2009-2015 and 2002-2015 and subjected to rigorous analysis using Johansen cointegration technique and vector error correction models. The results show that both market integration and speed of adjustments vary depending on the data period selected. Four market pairs were segmented during 2002-08 and three markets in 2009-15 periods. These segmented markets are concealed in 2002-15 period as all markets are found to be integrated. Davanagere APMC market takes central and leadership position in price formulation and transmission in the examined maize market across all three periods. Analysis of speed of adjustment has shown that with respect to Davanagere APMC market, all other markets respond more rapidly during 2002-08 (25%-90%) on a monthly basis than during 2002-15 (14%-66%). This finding is stands in sharp contrast to cointegration results which revealed that market integration is high during 2002-15 than 2002-2008 implying high price information flow. Thus, a great deal of caution is required before making any generalized conclusion regarding market integration and price transmission based on one data period. These findings imply that appropriate agricultural marketing policy measures can improve market integration and flow of price information over time.

KEY WORDS : Agricultural markets, Error correction, Market integration, Price analysis

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INTRODUCTION :

Spatially separated markets are said to be integrated if there is co-movements of the prices of the concerned markets and more generally if there is smooth transmission of price signals and information (Goletti *et al.*, 1995 and Ashoka, 2013). Alternatively, market integration is a function of speed (how fast) and magnitude (how much) of information is reflected in prices (Sendhil *et al.*, 2013). However, in reality the response of prices from one market to changes in another market prices is generally not instantaneous (Abdulai, 2000) due to many institutional factors and other restrictions which often generate an empirical lead-lag relationship between price changes in the two markets (Brosig *et al.*, 2011). Market integration studies make it possible to identify groups of integrated markets, so as to avoid duplication of interventions (Goletti *et al.*, 1995). Besides, by giving a

more detailed picture of the process of transmission of incentives across a marketing chain, knowledge of market integration is relevant to the success of policies such as price stabilization (Valera *et al.,* 2012).

There is a growing body of literature on spatial market integration of agricultural commodities. However, as new set of data is added over time, many studies merely extend the dataset period to include new data with limited attempt to compare the measures of market integration over time, with few exceptions like studies by Ghosh (2011) in India and Ahmad and Gjolberg (2015) in Pakistan. In Ghoshi's paper, the analysis has ended with establishing the number of cointegrating vectors using group trace statistic, during pre-reform and post-reform period in India. However, the disadvantage of group trace statistic is that while is indicates the number of cointegrating vectors in a group of markets, it does not show which pairs of markets are integrated, whether it is unidirectional or bidirectional and to what extent. Both group and pairwise trace statistics are analysed in this study.

Further, most studies on spatial integration of maize markets in Karnataka have ended with establishment of market integration (Ndlovu and Naik, 2015). However, often it is not adequate to just establish that markets are integrated; one would like to know the extent of spatial integration (Goletti *et al.,* 1995). Thus, the present study has examined the speed of adjustments to disequilibrium. However, price movement towards equilibrium may not occur in every period and is often distributed over time (Abdulai, 2000). Following Goletti *et al*. (1995) the shorter the time to complete this adjustment, the better information flow and the better integrated the markets. Conversely, weak market integration may transmit incorrect price signals to both producers and consumers (Alexander and Wyeth, 1994; Dawe, 2008 and Dutoit *et al*., 2009). The objective of this paper is first, to determine the degree of market integration and how that 'degree of integration' varies across three data periods, 2002-2008, 2009-2015 and 2002-2015. Second objective is to identify the central maize market and determine the speed of adjustment between the central market and other maize markets in Karnataka. Such an analysis can unveil certain limitations in terms of information that can be lost when cointegration analysis is done either on disaggregated (2002-2008 or 2009-15 only) or on the whole 2002- 2015 period.

MATERIALS AND METHODS :

The study used monthly modal price data of maize (in rupees per quintal) Published by the Department of Agricultural Marketing and Karnataka Agricultural Marketing Board for the period February 2002 - December 2015. Ten agricultural produce market committees (APMCs) with maximum quantities of maize arrivals were purposely selected as major maize markets in Karnataka based on three-year average of arrivals (Kallimath, 2009). The top ten APMCs are Davanagere, Hassan, Hirekerur, Ranibennur, Shikaripur, Shivamogga, Honnali, Badami, Hangal and Gowribidnur. While Haveri APMC is among the top ten major maize markets, it was not included in this analysis due to unavailability of data for a number of years considered for this study. The data has been divided into three categories, 2002-08, 2009-15 and 2002-15 periods in order to directly examine whether existence or absence of spatial market integration and speed of adjustment remain the same across different data periods.

The study used Johansen cointegration technique which has become standard method to generate a quantitative measure of market integration (Garcia-Hiernaux *et al.,* 2013; Ndlovu and Naik, 2015; Valera, *et al.,* 2012 and Goletti *et al.,* 1995). Under Johansen cointegration analysis, two series are said to have a common stochastic long-run trend when the trace statistic is higher than the critical value; the higher the trace statistic, the higher is the degree of cointegration (Valera *et al.,* 2012). Thus, the higher the trace statistic (λ_{trace}) for a pair of APMC's maize prices, the more strongly cointegrated the series are and, therefore, the higher the degree of integration between the two series and *vice versa*.

The existence of cointegration is indicative of interdependence; its absence indicates market segmentation (Goletti *et al.,* 1995). Cointegration process is well described in literature (Engle and Granger, 1987; Chirwa, 2000; Hallam and Conforti, 2003; Gujarat *et al.,* 2012 and Sahito, 2015). The first step in co-integration process is to test for stationarity of the price series (Adeoye *et al*., 2011) in order to overcome the problem of spurious regression that may arise from regressing non-stationary time series (Gujarat *et al*., 2012). To test for stationarity, the Augmented Dickey Fuller (ADF) technique was adopted as described in Adeoye *et al.* (2011) but earlier used Oladapo and Momoh (2007). ADF

technique involves running a regression of the form:

$$\Delta P_{it} = \partial P_{t-1} + \sum_{t=1}^{p} \beta_1 \Delta P_{t-1} + e_{it} \quad .....(1)$$

where, Δ= first difference operator, $\partial = 0$, implies the existence of a unit root in $P\partial_{it}$ or that the price series is non-stationary, i = commodity price series, *i.e.*, maize, t = time indicator, e_{it} is the error term. In this process, it is assumed that the maize price series is non-stationary or existence of unit root, *i.e.* H_o: $\partial = 0$. The test was conducted on the level and first difference of price series (Sendhil *et al.*, 2013).

The second step consists of carrying out the Johansen maximum likelihood tests using a linear deterministic trend in order to know the number of cointegrating vectors, using the model specified as:

$$\Delta X_t = \mu_t + \sum_{t=1}^{k} \Gamma X_{t-1} + \Pi X_{t-k} + \varepsilon t \quad ....(2)$$

where, X_t is an (N x 1) vector containing the series of interest (maize spatial prices series), Γ and Π = matrices of parameters, K = number of lags, and should be adequately large enough both to capture the short-run dynamics of the underlying Vector Auto-Regressive (VAR) and to produce normally distributed white noise residuals, ε_t = vector of white noise errors. The Johansen test gives an insight into the number of estimation equations that can be estimated (Adeoye *et al.*, 2011). The presence of at least one cointegrating relationship is necessary for the analysis of long run relationship of the prices to be plausible (Ahmad and Gjolberg, 2015; Ashoka, 2013 and Mensah-Bonsu *et al*., 2011). Besides, Johansen test generates trace statistics ($\lambda_{trace)}$) which indicates the degree of market integration integration (Valera *et al.*, 2012). In this analysis, changes in the trace statistic (λ_{trace}) values for a particular pair of APMC's are observed and compared over three time periods (2002-2008, 2009-2015 and 2002-2015).

The third and final step in ADF test involves the Granger causality test in order to determine the direction of causality or shock transmission. When two price series are co-integrated and stationary, one may proceed to carry out the Granger causality test (Gujarat *et al.*, 2012) using the model specified as :

$$\Delta P_{it} = \sum_{i=1}^{m} \alpha_i \Delta P_{t(t-1)} + \sum_{j=1}^{n} \alpha_j \Delta P_{j(t-1)} + \varepsilon_t \quad .....(3)$$

where, m and n are the numbers of lags determined by a suitable information criterion *i.e.* Akaike and Schwarz information criterion. Rejection of the Null hypothesis indicates that prices in market j granger-cause prices in market i. Here it is hypothesized that the price of maize in one market does not determine (granger cause) the price in the other market.

Granger causality test was performed and the results, not presented here in the interest of brevity, showed that Davanagere (DAVA) APMC is the central market across all the three data periods. However, determining Granger causality was not the main motivation of this study, but a means to identify the central market whose influence on other maize markets is of interest Vector error correction model (VECM) analysis. So the study proceeded to test the speed of price adjustment by employing the VECM which captures deviations from long-run equilibrium (Brosig *et al.*, 2011). VECM is estimated once cointegration between the series is established (Ahmad and Gjolberg, 2015) and was performed only for the cointegrated market pairs across the three periods. The price series were transformed into logarithmic form (Ahmad and Gjolberg, 2015) before running the VECM in which price adjustments induced by deviations from the long-run equilibrium are assumed to and linear function (Sahito, 2015). The co-efficients of the error correction terms represent the speed at which the price series adjust to the long-run disequilibrium errors (Asteriou and Hall, 2007; Ahmad and Gjolberg, 2015). If less than zero, the variables converge to long-run equilibrium and if positive and zero, the variables diverge from long-run equilibrium (Sendhil *et al.*, 2013).

RESULTS AND DATA ANALYSIS :

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Stationarity test of price series in major maize markets in Karnataka :

A series or variable is considered stationary when the Augmented Dickey-Fuller (ADF) t-statistic is smaller in absolute term than the critical values. Price series that follow a stochastically stationary process would not react or adjust to any shock to clear the market and further, reveal a poorly developed market, where some participants have market control (Garcia-Hiernaux *et al*., 2013). A variable that is already stationary is integrated of order zero, $I(0)$ while the non-stationary series is said

to be integrated of order 1 if it has to be differenced once to become stationary, written as *I* (1) (Oladapo and Momoh, 2007). Table 1 shows the results of unit root test of the maize prices using the ADF procedure for 2002-08, 2009-15 and 2002-15 data categories in major maize markets. The results show that all the price series are non-stationary at level. The values of the ADF t-statistic were smaller in absolute term than their critical values at all significance levels; the Null hypothesis of non-stationarity of series is accepted at 1 per cent level of significance. However, the Null hypotheses of a unit root were rejected after first differencing for all the selected maize markets at 1 per cent level of significance. This finding confirms earlier studies which found that commodity prices are stationary at their first difference (Abdulai, 2000; Chirwa, 2000; Mensah-Bonsu *et al*., 2011; Ghosh, 2011 and Ndlovu and Naik, 2015). Hence, all the selected ten maize markets were considered for cointegration test.

Co-integration (Johansen maximum likelihood) test for the major maize markets in Karnataka :

To examine the hypothesis that there are 'r' co-integrating equations or existence of long run relationship between the variables, Johansen cointegration test was performed for both group of all selected markets (Ghosh, 2011) and for market pairs (Sahito, 2015) across the three data periods. The results for group test are presented in Table 2 and for market pairs in Table 3, indicating the number of cointegrating long run relationships. As

Table 1: Results of unit root test for major maize markets in Karnataka (2002-08, 2009-15 and 2002-15)

Period/ market	2002-2008		2009-2015		2002-2015	
	Level ADF	First difference	Level ADF	First difference	Level ADF	First difference
Davanagere APMC market	-1.12	-8.24***	-1.22	-7.63***	-0.48	-11.17***
Badami APMC market	-1.70	-8.49***	-1.07	-12.02***	-0.40	-15.99***
Gowribidnur APMC market	-1.86	-8.65***	-1.81	-8.94***	-1.21	-12.66***
Hangal APMC market	-2.54	-11.03***	-2.47	-12.16***	-1.36	-16.99***
Hassan APMC market	-3.32	-14.35***	-2.10	-10.94***	-1.34	-18.97***
Hirekerur APMC market	-1.65	-10.97***	-1.84	-6.65***	-0.71	-11.97***
Ranibenur APMC market	-1.94	-9.94***	-2.57	-11.65***	-1.27	-16.16***
Shikaripur APMC market	-0.26	-8.28***	-2.72	-9.19***	-1.26	-10.98***
Shivamogga APMC market	-2.03	-10.18***	-1.43	-13.54***	-0.92	-17.98***
Honnali APMC market	0.70	-6.65***	-2.31	-11.67***	-1.10	-15.87***

Source: Author' Computation. Shikaipur 2002-08 data series were tested without trend and intercept. All others were tested with ntercept.
Critical values: 1%=-3.513344, 5%=-2.898623, 10%=-2.586605. *** indicate significance of value at P=0.1

Table 2 : Results of Johansen co-integration test for group of maize markets in Karnataka

Null hypothesis	2002-2008		2009-2015		2002-2015	
	Trace statistic	0.05 critical value	Trace statistic	0.05 critical value	Trace statistic	0.05 critical value
r=0	303.98**	239.24	315.29**	239.23	392.54**	239.24
r≤1	230.39**	197.37	247.10**	197.37	315.99**	197.37
r≤2	164.63*	159.53	194.30**	159.53	252.65**	159.53
r≤3	114.16	125.62	145.77**	125.61	194.51**	125.62
r≤4	81.38	95.75	102.46*	95.75	144.63**	95.75
r≤5	55.92	69.82	67.65	69.82	99.44**	69.82
r≤6	33.12	47.86	40.32	47.86	62.90**	47.86
r≤7	17.26	29.80	16.36	29.80	32.44*	29.80
r≤8	5.06	15.49	4.86	15.49	13.23	15.49
r≤9	0.00	3.84	0.46	3.84	0.16	3.84

Source: Computed by authors. Trace test indicates 3, 5 and 8 co-integrating eqn(s) at the 0.05 level for period 2002-08, 2009-15 and 2002-15, respectively.
* and ** indicate significance of values at P=0.01 and 0.05, respectively. **MacKinnon-Haug-Michelis (1999) p-values. No of lags=2, selected using Akaike Information Criterion

indicated in Table 2, the group trace statistics show that the null hypothesis of no cointegrating relationships can be rejected at 5 per cent significance level for all the maize market price series and in all the data periods. The trace statistics show that the number of cointegrating equations has improved significantly across the three data period. There are at least 3 co-integrating relationships in 2002-08 period, which has improved to 5 cointegrating equations in 2009-15 period and further improved to 8 cointegrating equations in 2002-15 period taken together. That means more markets which were not integrated during 2002-08 period have become integrated in the later periods. Apart from that, the values of trace statistics have also increased from one data period to another implying that the degree of integration has become stronger from 2002 to 2015. While group cointegration test results do not indicate which market pairs are integrated or not, these findings are crucial for policy as they show that markets that are not integrated in one period may be integrated in another or extended period under consideration, if appropriate policy measures are undertaken.

Since group cointegration test simply provides a general picture of cointegrating long-run relationships among price series but fails to indicate the specific market pairs that are integrated or not, pairwise cointegration test was conducted in order to identify the particular markets which were segmented in an earlier period but are integrated in a later period. The test results of pairwise cointegration are presented in Table 3. There are 45 possible market pairs from a group of ten maize markets (APMCs) and the null hypothesis of no cointegration (r=0) is rejected in all market pairs in 2002-15 period, but not rejected in some few cases in 2002-08 and 2009-15 periods. The results show that about 9 per cent (4 out of 45) of the market pairs were not integrated in 2002-08, namely, Hirekerur-Ranibenur APMCs, Shivamogga and Honnali APMCs, Badami and Honnali APMCs and Gowribidnur-Honnali APMCs. During 2009-15 period, about 7 per cent (3 out of 45) of the market pairs were not integrated; Hirekerur-Shivamogga APMCs, Shikaripur-Shivamogga APMCs and Shivamogga-Gowribidnur APMCs. When 2002-2015 data is considered together, all the 45 market pairs are found to be integrated and highly significant at 1 per cent level. Overall, the magnitude of trace statistics for 25 market pairs are lower during 2009-15 than during 2002-08 period, but all are higher during 2002-15 period than during 2002-08 period which implies that the degree of integration has improved over the years.

Another interesting finding is that all the market pairs which were not integrated in 2002-08 period are found to be integrated in 2009-15 period. On the other hand, 3 market pairs which were strongly integrated in 2002-08 period were found to be segmented in 2009-15 period. The implication is that evidence of existence or non-existence of market integration cannot be generalized, but restricted to a particular data period, as the status may change depending on the data period considered for analysis. Thus, spatial market integration is time-dependent; evidence of market integration in one period does not guarantee existence of cointegration in another period. These variations are concealed when analysis is based on the 2002-2015 period as a single block, where all the market pairs are found to be integrated. Therefore, assessment of market integration based on a disaggregated data periods offers more information and clarity of the dynamics of market integration between spatial markets.

Granger causality test was also performed to detect the direction of causality between different pairs of maize markets. The results, not presented here in the interest of brevity but available from the authors upon request, show that Davanagere is the central market in all the three different time periods as it granger-causes all other markets.

Pairwise VECM estimations were performed to capture the co-efficients for speed of adjustments in both directions for all the 45 market pairs for 2002-15 period but four market pairs in 2002-08 and three pairs in 2009-15 periods were excluded because Johansen cointegration test showed that these markets did not to exhibit a long run relationship. The results of the estimated co-efficients are reported in Table 4. Diagnostic tests of residual autocorrelation were performed for the error correction models using Serial correlation LM test and the results indicated that the residuals were not significantly correlated. Akaike Information Criterion was used for selection of lags, which suggested the lag of the order two. Since Davanagere APMC is central market as established earlier by granger causality test, with particular interest, the speed of adjustments is examined from pairwise VECM estimates particularly in market pairs containing the central market as one of the elements.

All market pairs containing Davanagere APMC (Dava) have coefficients with expected negative sign

Table 3: Results of Pairwise Johansen cointegration test for 2002-08, 2009-15 and 2002-15 series

Market pair	Null	Trace stat (2002-08)	Trace stat (2009-15)	Trace stat (2002-15)	Market link	Null	Trace stat (2002-08)	Trace stat (2009-15)	Trace stat (2002-15)
Dava-Hass	r=0 r≤1	22.49*** 0.93	23.29*** 2.59	40.59*** 0.28	Hire-Honn	r=0 r≤1	18.79** 0.51	24.93*** 2.25	38.67*** 0.51
Dava-Hire	r=0 r≤1	19.41*** 0.17	24.26*** 2.33	32.33*** 0.25	Rani-Shik	r=0 r≤1	24.97*** 3.69	25.79*** 3.15	35.56*** 0.71
Dava-Rani	r=0 r≤1	26.92*** 0.81	24.27*** 2.70	43.39*** 0.31	Rani-Shiv	r=0 r≤1	29.33*** 2.18	18.94** 2.70	32.31*** 0.71
Dava-Shik	r=0 r≤1	30.20*** 1.04	28.04*** 2.64	37.41*** 0.20	Rani-Bada	r=0 r≤1	32.05*** 2.26	33.83*** 1.89	57.18*** 0.31
Dava-Shiv	r=0 r≤1	24.46*** 0.86	17.27** 2.92	26.72*** 0.29	Rani-Gowr	r=0 r≤1	33.95*** 2.80	22.10*** 4.44**	42.31*** 1.37
Dava-Bada	r=0 r≤1	22.36*** 1.33	28.87*** 1.71	40.82*** 0.20	Rani-Hang	r=0 r≤1	23.41*** 4.76**	31.39*** 3.16	49.82*** 1.08
Dava-Gowr	r=0 r≤1	21.68*** 1.15	21.52*** 2.37	32.98*** 0.52	Rani-Honn	r=0 r≤1	28.37*** 1.35	26.59*** 3.37	48.58*** 0.89
Dava-Hang	r=0 r≤1	29.70*** 1.67	26.88*** 2.35	48.52*** 0.31	Shik-Shiv	r=0 r≤1	27.76*** 1.68	12.15 2.34	22.66*** 0.32
Dava-Honn	r=0 r≤1	17.52** 0.45	24.52*** 2.50	34.55*** 0.29	Shik-Bada	r=0 r≤1	27.97*** 2.68	20.70*** 1.44	34.38*** 0.15
Hass-Hire	r=0 r≤1	22.76*** 0.62	24.40*** 2.17	40.64*** 0.38	Shik-Gowr	r=0 r≤1	29.16*** 2.86	24.52*** 3.55	37.38*** 0.91
Hass-Rani	r=0 r≤1	28.95*** 3.25	23.24*** 2.48	45.35*** 0.48	Shik-Hang	r=0 r≤1	31.73*** 3.84*	29.23*** 2.69	39.47*** 0.60
Hass-Shik	r=0 r≤1	29.16*** 7.28***	20.71*** 3.04	33.56*** 0.46	Shik-Honn	r=0 r≤1	25.96*** 2.12	23.90*** 2.98	35.31*** 0.75
Hass-Shiv	r=0 r≤1	27.21** 1.89	17.01** 2.76	35.29*** 0.46	Shiv-Bada	r=0 r≤1	20.33*** 2.50	20.31*** 3.07	23.84*** 0.62
Hass-Bada	r=0 r≤1	31.03*** 2.64	22.61*** 1.66	42.95*** 0.18	Shiv-Gowr	r=0 r≤1	21.37*** 2.61	12.04 3.78	21.07*** 1.53
Hass-Gowr	r=0 r≤1	24.57*** 2.96	19.77** 3.00	37.03*** 0.87	Shiv-Hang	r=0 r≤1	27.69*** 2.99	19.40** 2.77	34.22*** 0.92
Hass-Hang	r=0 r≤1	28.73*** 3.22	26.87*** 2.51	47.47*** 0.68	Shiv-Honn	r=0 r≤1	13.49 0.98	19.65** 2.73	29.05*** 0.84
Hass-Honn	r=0 r≤1	22.84*** 1.66	24.65*** 3.19	42.70*** 0.76	Bada-Gowr	r=0 r≤1	20.17*** 2.51	16.15** 0.67	20.09*** 0.07
Hire-Rani	r=0 r≤1	15.36 0.46	33.18*** 2.57	45.14*** 0.46	Bada-Hang	r=0 r≤1	21.73*** 2.76	30.64*** 1.361	45.60*** 0.12
Hire-Shik	r=0 r≤1	27.07*** 0.45	23.76*** 2.32	34.04*** 0.46	Bada-Honn	r=0 r≤1	15.37 1.39	26.66*** 1.33	37.29*** 0.13
Hire-Shiv	r=0 r≤1	18.82** 0.68	14.31 2.51	28.57*** 0.56	Gowr-Hang	r=0 r≤1	24.82*** 2.88	25.66*** 3.62	34.63*** 1.31
Hire-Bada	r=0 r≤1	22.31*** 0.49	51.52*** 1.435762	33.96*** 0.16	Gowr-Honn	r=0 r≤1	14.11 0.80	23.17*** 3.89**	36.77*** 1.21
Hire-Gowr	r=0 r≤1	20.40*** 0.75	15.91** 2.43	29.68*** 0.67	Hang-Honn	r=0 r≤1	17.11** 3.91**	35.39*** 2.91	43.88*** 0.97
Hire-Hang	r=0 r≤1	28.28*** 0.77	30.36*** 2.13	49.09*** 0.47					

Critical value @0.05 level= 15.49471 (for r=0) and 3.841466 (for r ≤1). * , ** and *** indicate significance of values at P=0.1, 0.05 and 0.01 Dava = Davanagere,
Hass = Hassan, Hire = Hirekerur, Rani = Ranibenur, Shik = Shikaipur, Shiv = Shivamogga, Bada = Badami, Hang = Hangal, Gowr = Gowribidnur and Honn = Honnali APMC market.

Table 4: Pairwise VECM Results for maize markets in Karnataka, 2002-08, 2009-15 and 2002-15 series

Market pair	Speed of Adj (2002-08)	Speed of Adj (2009-15)	Speed of Adj (2002-15)	Market pair	Speed of Adj (2002-08)	Speed of Adj (2009-15)	Speed of Adj (2002-15)
Hass-Dava	-0.926*** -0.021	-0.493*** 0.160*	-0.660*** 0.091*	Hire-Honn	-0.230* 0.232***	-0.123 0.679***	-0.174** 0.513*
Hire-Dava	-0.305** 0.204**	-0.503*** 0.047	-0.314*** 0.166**	Rani-Shik	0.009 0.339***	-0.336** 0.421***	-0.213*** 0.393***
Rani-Dava	-0.648*** 0.032	-0.711*** 0.067	-0.655*** 0.079	Rani-Shiv	-0.740*** 0.267	-0.395** 0.286**	-0.358*** 0.290***
Shik-Dava	-0.896*** -0.037	-0.821*** 0.017	-0.587*** 0.025	Bada-Rani	-0.095 0.694***	-0.057 0.990***	-0.074 0.896***
Shiv-Dava	-0.745*** -0.032	-0.656*** -0.030	-0.534*** -0.010	Rani-Gowr	-0.726*** 0.175	-0.576*** 0.219**	-0.619*** 0.188**
Bada-Dava	-0.301*** 0.212*	-0.143 -0.566***	-0.212** 0.374***	Rani-Hang	-0.494*** 0.198	-0.633*** 0.424***	-0.489*** 0.381***
Gowr-Dava	-0.362*** 0.162**	-0.697*** -0.123	-0.370*** 0.106	Rani-Honn	-0.594*** 0.149	-0.426*** 0.489***	-0.484*** 0.398***
Hang-Dava	-0.619*** 0.212**	-1.143*** -0.118	-0.833*** 0.049	Shik-Shiv	-0.845*** -0.040	-	-0.309*** 0.102*
Honn-Dava	-0.245*** 0.107	-0.792*** -0.006	-0.500*** 0.079	Shik-Bada	-0.781*** 0.009	-0.640*** -0.128	-0.525*** 0.012
Hass-Hire	-0.822*** 0.143*	-0.439*** 0.178**	-0.584*** 0.156***	Shik-Gowr	-0.782*** 0.023	-0.605*** 0.143	-0.500*** 0.082
Hass-Rani	-0.700*** 0.257***	-0.225** 0.494***	-0.365*** 0.426***	Shik-Hang	-0.828*** 0.072	-0.595*** 0.311*	-0.418*** 0.197***
Hass-Shik	-0.031 0.268***	-0.233 0.508***	-0.246*** 0.379***	Shik-Honn	-0.744*** 0.004	-0.414** 0.311	-0.432*** 0.131*
Hass-Shiv	-0.130 0.459***	-0.161 0.372***	-0.357*** 0.311***	Shiv-Bada	-0.465*** 0.086	-0.708*** -0.265**	-0.502*** -0.113
Hass-Bada	-0.999*** 0.085	-0.557*** 0.111	-0.698*** 0.112**	Shiv-Gowr	-0.434*** 0.186	-	-0.437*** 0.011
Hass-Gowr	-0.813*** 0.090	-0.262** 0.262***	-0.500*** 0.177***	Shiv-Hang	-0.607*** 0.408**	-0.454*** 0.297*	-0.406*** 0.296***
Hass-Hang	-0.796*** 0.196*	-0.419*** 0.417***	-0.504*** 0.326***	Shiv-Honn	-	-0.397** 0.431**	-0.403*** 0.292***
Hass-Honn	-0.762*** 0.076	-0.249* 0.562***	-0.490*** 0.322***	Bada-Gowr	-0.266** 0.353*	0.148 0.543***	-0.049 0.385***
Hire-Rani	-	-0.208** 0.826***	-0.172** 0.629***	Bada-Hang	-0.174 0.662***	0.040 1.020***	0.026 0.796***
Hire- Shik	-0.025 0.430***	-0.034 0.678***	-0.050 0.525***	Bada-Honn	-	0.050 0.775***	-0.035 0.587***
Hire- Shiv	-0.130 0.459***	-	-0.027 0.521***	Gowr-Hang	-0.258 0.539***	-0.323** 0.578**	-0.120 0.488***
Bada-Hire	-0.275*** 0.320**	0.192 1.022***	-0.107 0.427***	Gowr-Honn	-	-0.126 0.603***	-0.149 0.490***
Hire-Gowr	-0.148 0.381***	-0.085 0.474**	-0.213** 0.342***	Hang-Honn	-0.352* 0.189	-0.381* 0.762***	-0.409*** 0.455***
Hire-Hang	-0.202 0.615***	-0.167 0.960***	-0.168* 0.664***				

*, ** and *** indicate significance of values at P=0.1, 0.05 and 0.01, respectively   Dava = Davanagere, Hass = Hassan, Hire = Hirekerur, Rani = Ranibenur, Shik = Shikaipur, Shiv = Shivamogga, Bada = Badami, Hang = Hangal, Gowr = Gowribidnur and Honn = Honnali APMC market

and statistically significant. In 2002-08 period, the vector error correction co-efficients for the first market pair are -0.926 for Hassan market (Hass) and -0.021 for Davanagere market (Dava). That means Hassan market prices adjust or eliminate about 93 per cent of the previous deviation from long-run equilibrium caused by changes in Davanagere market prices within one month. Similarly, Davanagere market prices adjust only about 2 per cent of the deviation from long-run equilibrium relationship within one month. Here, Hassan market adjusts itself for the previous disequilibrium errors more rapidly towards long-run equilibrium compared to Davanagere market as indicated by their magnitude of adjustment. This finding also signifies the direction of causality; Davanagere market granger-causes Hassan market, unidirectionally. The negative sign on co-efficients suggests that the adjustment is from a higher price shock (*i.e.* price rise) to the long-run price level (Mensah-Bonsu *et al.*, 2011) and the magnitude of co-efficient for Hassan market indicates more information flow compared to Davanagere market with error correction co-efficient of 2 per cent.

Moving from 2002-08 to 2002-15 period, the adjustment co-efficients for Hassan-Davanagere market pair show a sharp decline; -0.493, 0.160, respectively, in 2009-15 period and -0.660, 0.091, respectively, in 2002-15 period. This declining pattern can be observed in a number of market pairs across the three data periods. The results also indicate that in 2002-08 data period, the adjustment co-efficients for 18 market pairs were below 50 per cent for each market and 17 and 27 market pairs for 2009-15 and 2002-15 data periods. These results suggest that prices adjusted more rapidly in 2002-08 period than 2002-15 data period taken together. That means analysis that is based on the entire 2002-15 data period will show that majority of maize markets in Karnataka have a partial and weak adjustment/integration compared to earlier data periods. This finding stands in sharp contrast to Johansen cointegration test which indicated that integration among the markets has improved during 2002-15 data period than during 2002-08 data period.

Conclusion :

The study examined spatial market integration and price adjustment in ten major maize markets in Karnataka from February 2002–December 2015 split into three data periods. The stationary test showed that prices were not stationary at level. At first difference, prices became stationary thereby rejecting the null hypothesis of non-stationarity in maize prices. The results of group granger causality test indicated the existence of at least four co-integrating equations. Davanagere APMC was found to be a central market across the three data periods thereby playing a leadership role in maize price formation and transmission as its maize price unidirectioanally influences maize prices in all other markets. Thus, Davanagere APMC could be the target of maize price policy interventions. While some markets were segmented in 2002-08 and 2009-15 periods, all market pairs are integrated 2002-15 period is not split, which implies higher level of maize market development in Karnataka. The study also found that maize markets adjust fast to price signals arising from Davanagere APMC though in some cases the speed of adjustment has declined across the data periods. It can be concluded that great caution is necessary before generalizing spatial market integration findings from only one data period.

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